Enhancing Groundwater Recharge with Stormwater

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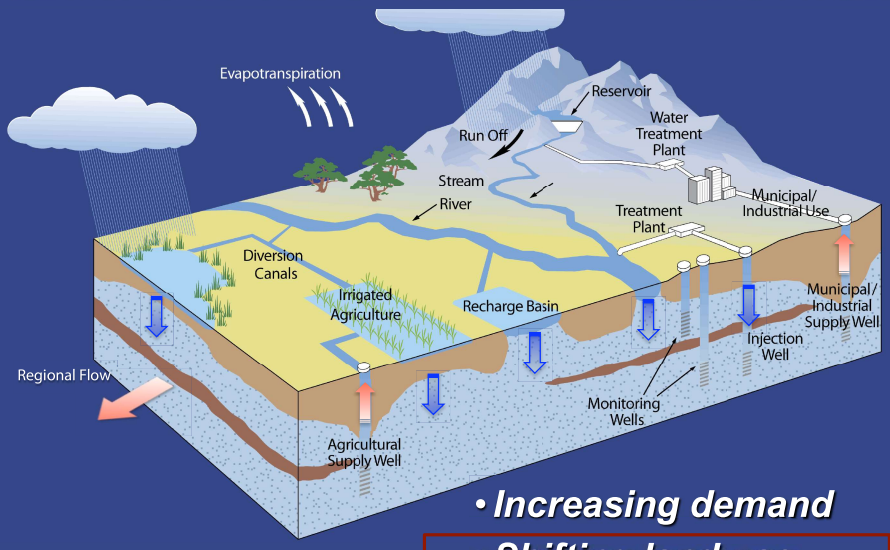
STORMS Seminar Series
California Water Boards, Sacramento, CA
30 May 2017

The Recharge Initiative
Replenish • Recover • Restore
www.rechargeinitiative.org

California's GW Supplies Face a Triple Threat



- *Increasing demand*
- *Shifting land use*
- *More intense rainfall*

Less GW Recharge

The Recharge Initiative

- ***Map*** locations where enhanced recharge might be best accomplished
- ***Model*** availability of stormwater from hill slopes
- Design/create field projects and ***measure***/validate:
  - benefits to water *supply*
  - improvements to water *quality*
- ***Monetize*** activities and polities that incentivize stakeholders and strengthen partnerships

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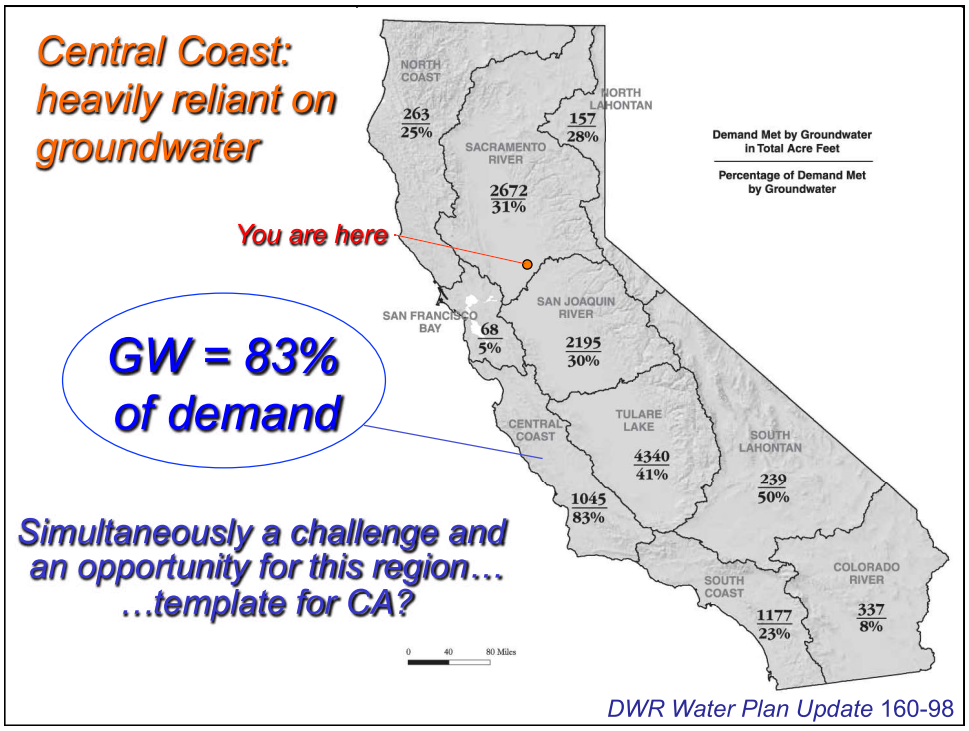
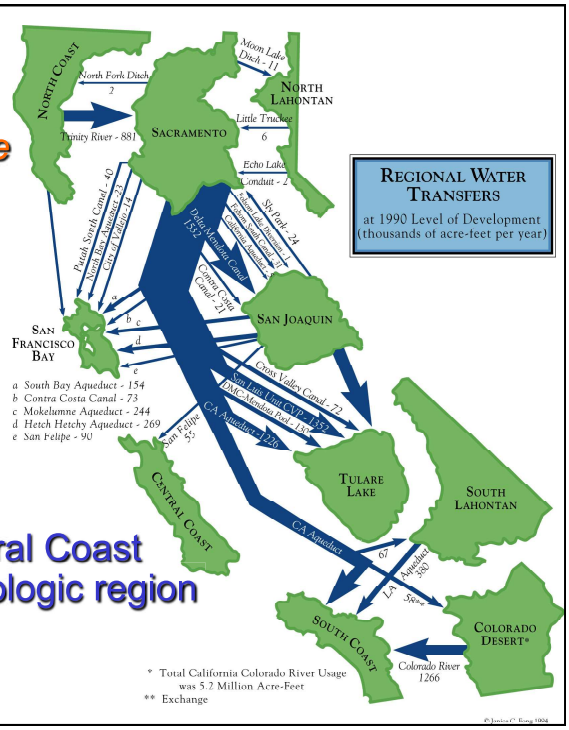


Central Coast: Virtually "off the grid" in terms of large-scale water transfers



Central Coast hydrologic region

modified from *Mount (1995)*

Different Scales of Managed Recharge

Low-impact development (LID)

Regional spreading grounds

Different Scales of Managed Recharge

Low-impact development (LID)	Regional spreading grounds
1-10 af/yr per site	10^4-10^5 af/yr per site

Stormwater as a Source for Managed Aquifer Recharge (MAR)

Low-impact development (LID)	***Distributed Stormwater Collection → MAR (DSC-MAR)***	Regional spreading grounds
1-10 af/yr per site	10^2-10^3 af/yr per site	10^4-10^5 af/yr per site

Pajaro River and Pajaro Valley Groundwater basins

PVGB, lower PR basin, mostly Santa Cruz and northern Monterey Counties

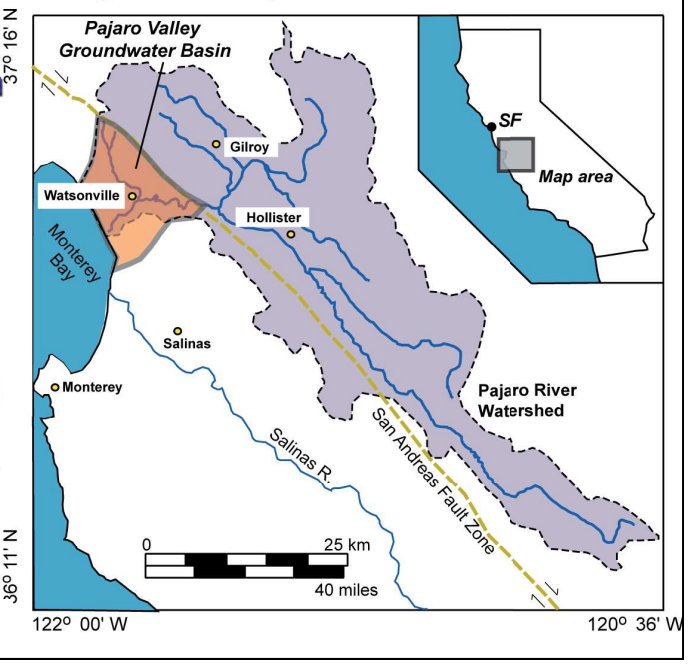
Primary fresh water resource is groundwater

PVWMA: Special Act district (1984)

PVWMA serves 70,000 acres, 30,000 irrigated

Major crops:
Strawberries, cane berries, table crops, organic (30%)

→$1B farm revenue



Overdraft is a regional challenge

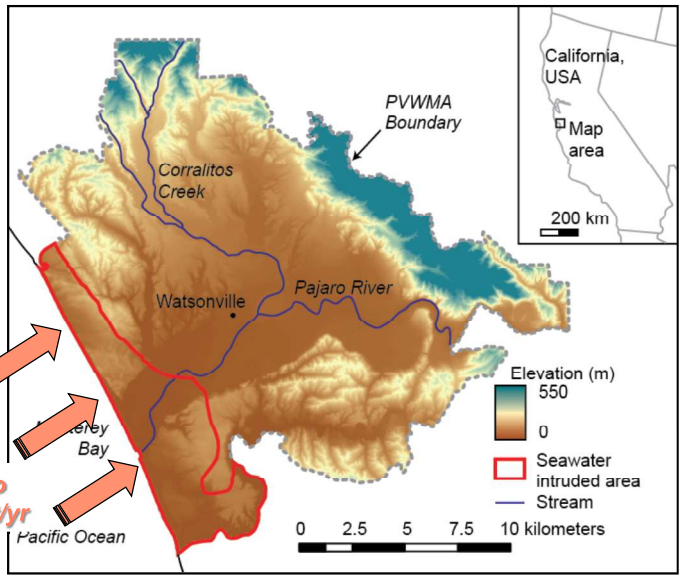
Pumping:
~55k ac-ft/yr

City of Watsonville:
~7k ac-ft/yr

Sustainable yield:
40k–45k (?) ac-ft/yr (depends on pumping distribution, time horizon, natural variability)

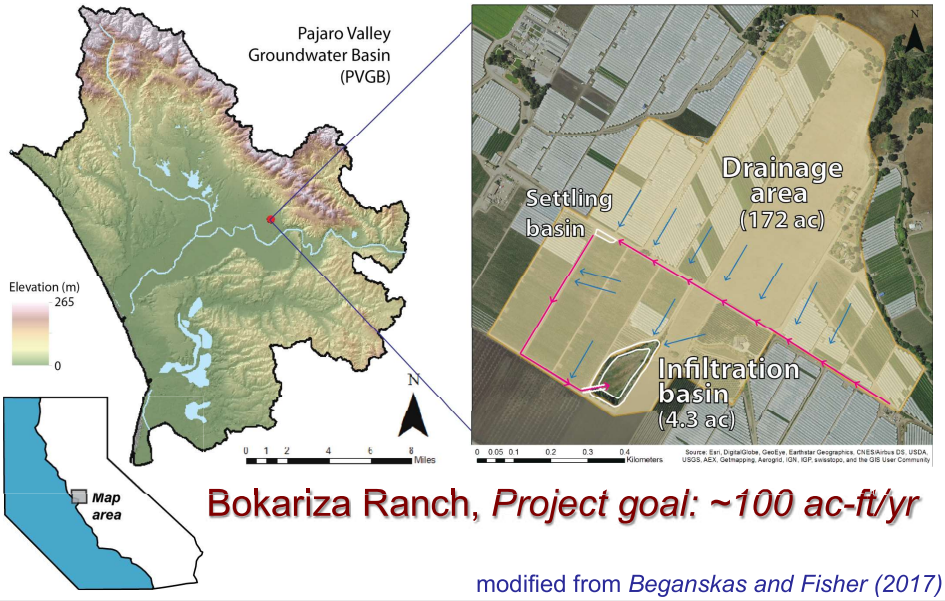
Overdraft:
10k–15k (?) ac-ft/yr (depends on definition, annual conditions, ***definitely large****)*

200 to 350 ft/yr



map from PVWMA, 2012

Distributed Stormwater Collection – Managed Aquifer Recharge (DSC-MAR)



Bokariza Ranch, *Project goal: ~100 ac-ft/yr*

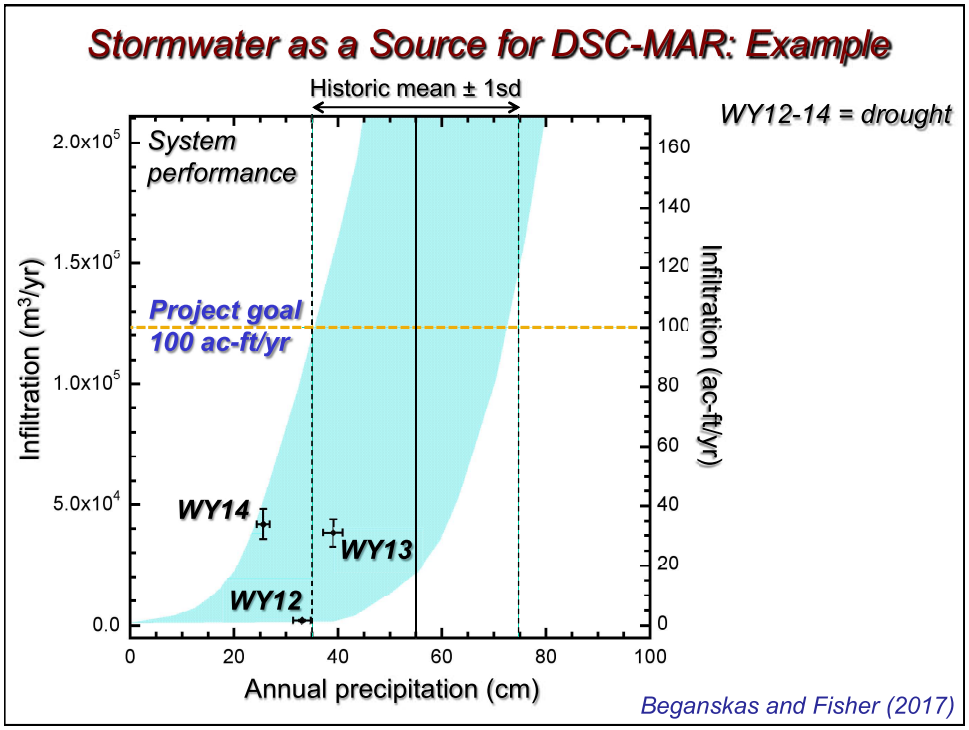
modified from *Beganskas and Fisher (2017)*

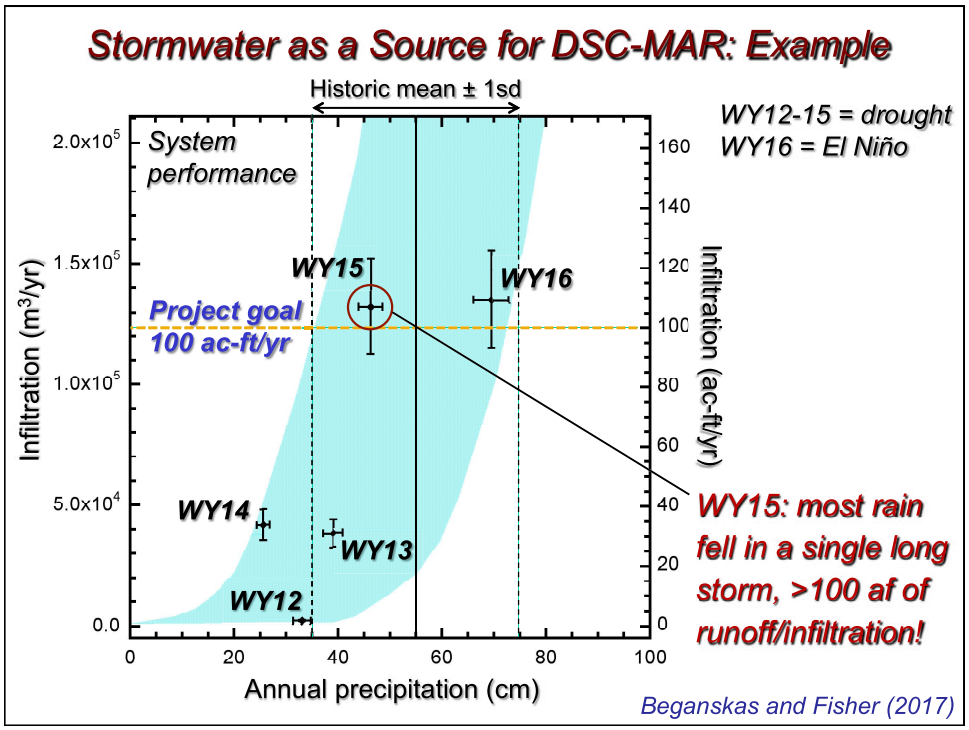
Stormwater as a Source for DSC-MAR: Example

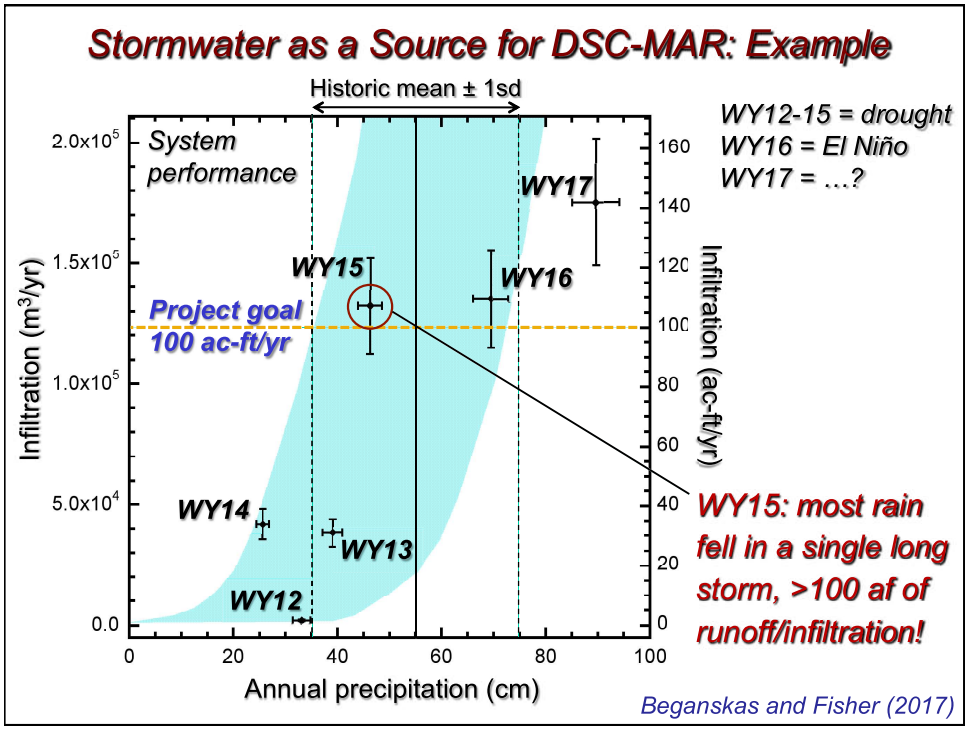
Instrumented 2011-present

- Precipitation
- Water level (culvert, basin)
- Infiltration rate
- Sediment accumulation

Real-time sensor network


Stormwater as a Source for DSC-MAR: Example
Historic mean ± 1sd
WY12-14 = drought
System performance
Project goal 100 ac-ft/yr
WY14
WY13
WY12
Infiltration (m³/yr)
Infiltration (ac-ft/yr)
Annual precipitation (cm)
Beganskas and Fisher (2017)


Stormwater as a Source for DSC-MAR: Example
Historic mean ± 1sd
WY12-15 = drought
WY16 = El Niño
System performance
Project goal 100 ac-ft/yr
WY15
WY16
WY14
WY13
WY12
WY15: most rain fell in a single long storm, >100 af of runoff/infiltration!
Infiltration (m³/yr)
Infiltration (ac-ft/yr)
Annual precipitation (cm)
Beganskas and Fisher (2017)


Stormwater as a Source for DSC-MAR: Example
Historic mean ± 1sd
System performance
WY12-15 = drought
WY16 = El Niño
WY17 = …?
WY17
WY15
WY16
Project goal
100 ac-ft/yr
WY14
WY13
WY12
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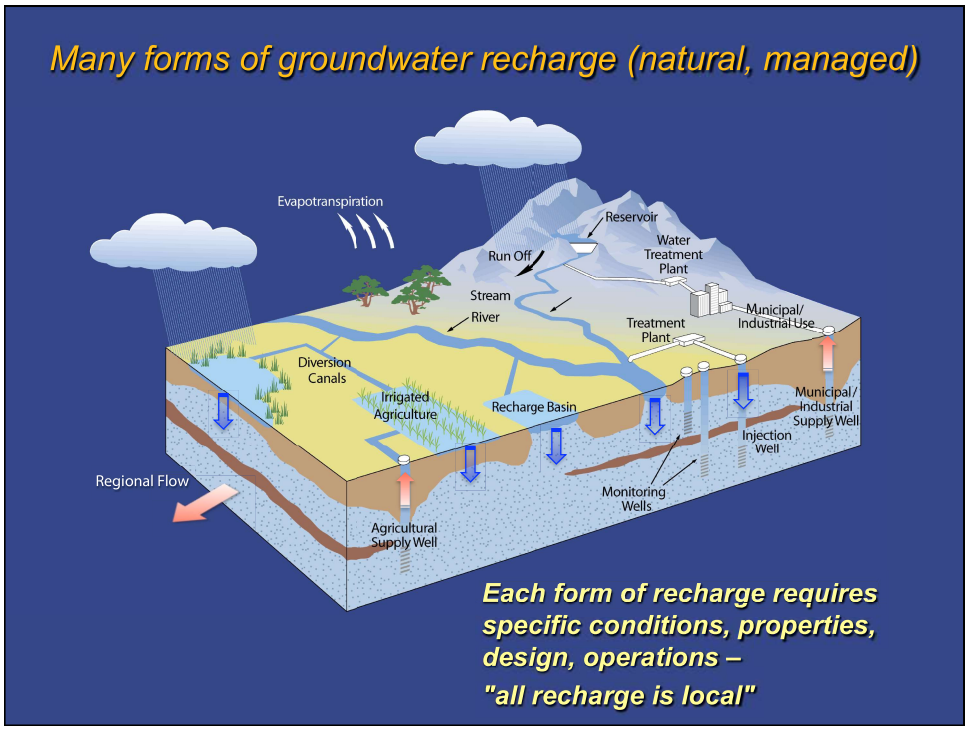
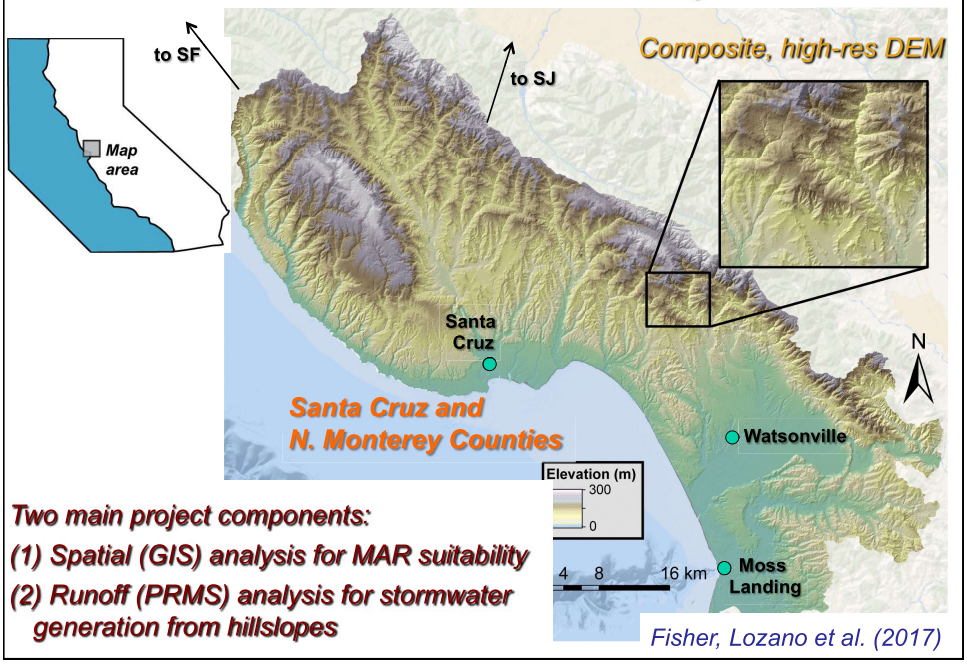

Many forms of groundwater recharge (natural, managed)
Evapotranspiration
Reservoir
Water Treatment Plant
Run Off
Stream
River
Municipal/ Industrial Use
Treatment Plant
Diversion Canals
Irrigated Agriculture
Recharge Basin
Municipal/ Industrial Supply Well
Injection Well
Regional Flow
Monitoring Wells
Agricultural Supply Well
Each form of recharge requires specific conditions, properties, design, operations –
"all recharge is local"

Where to Place DSC-MAR Projects?



Two main project components:

(1) Spatial (GIS) analysis for MAR suitability

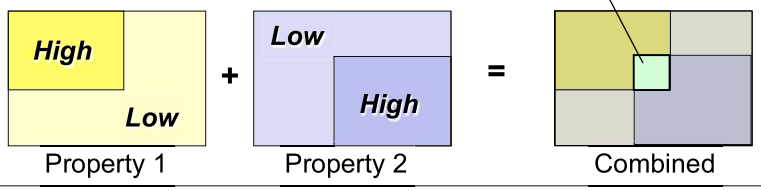
(2) Runoff (PRMS) analysis for stormwater generation from hillslopes

Fisher, Lozano et al. (2017)

Combining spatial data to assess MAR Suitability

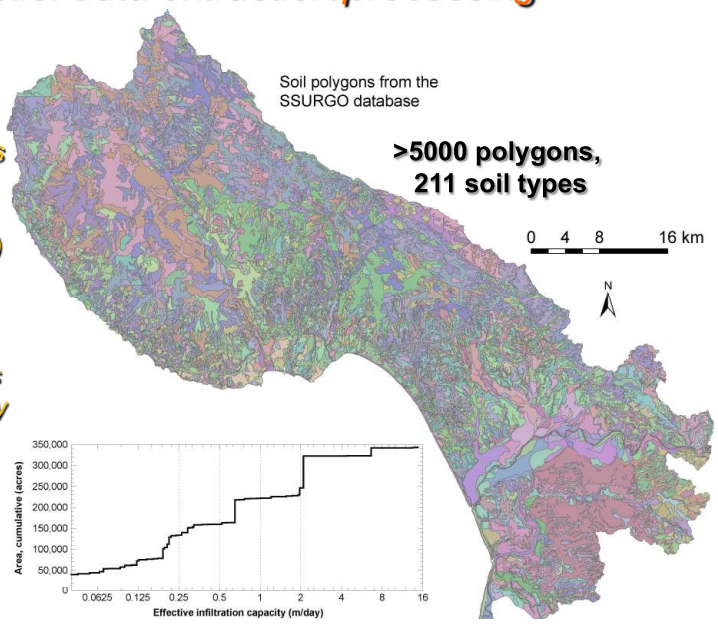
- *Compile, patch, reconcile, regrid, reproject datasets*
- *For each dataset, categorize for conditions that are more/ less favorable for DSC-MAR*
- *Combine datasets to create maps showing composite suitability*

Schematic example:



Regional Soils: data extraction/processing

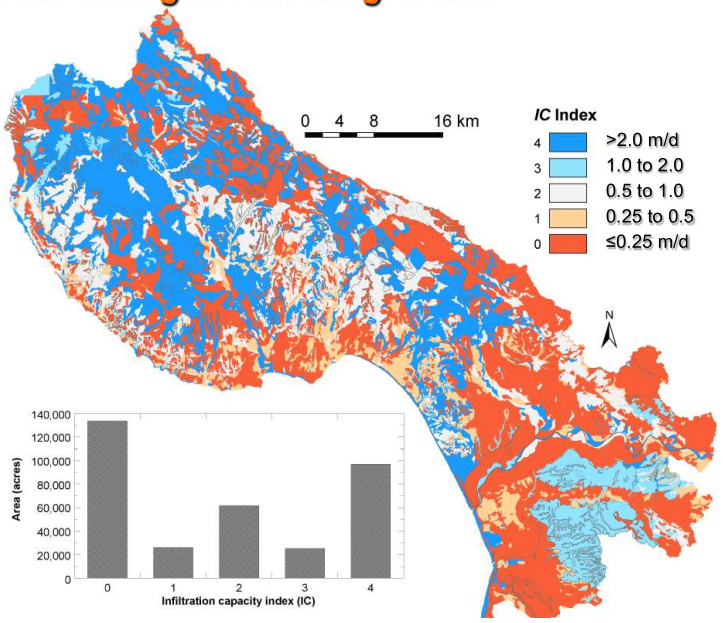
- *Extract shape files and Access database from SSURGO (USDA)*
- *Merge shapes with properties, process to assess infiltration capacity*



Teo et al. (2017) – in prep

Regional Soils: Categorical Assignment

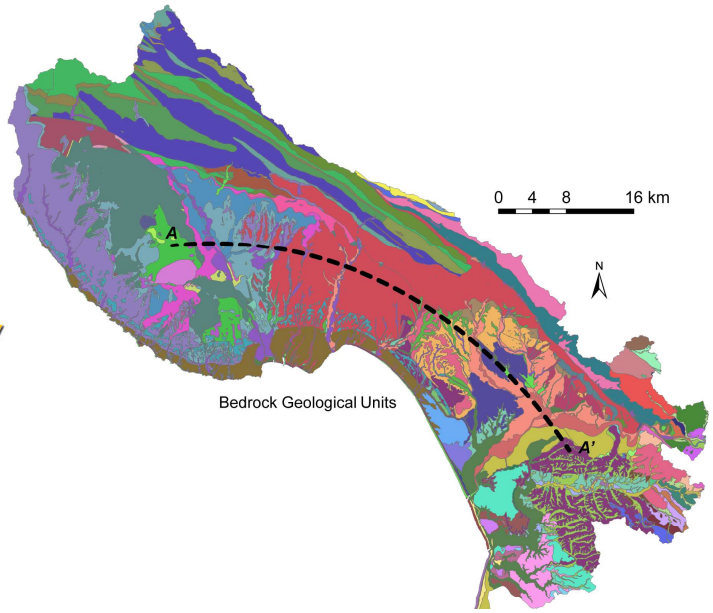
- *Combine data from multiple soil layers*
- *Assign IC index on a $\log_2$ scale (distributes wide range of values)*



Teo et al. (2017) – in prep

Regional Bedrock: Unit Classification

- Combine regional data from multiple reports/maps
- Evaluate unit by unit to determine which bedrock units are/might be/ are not aquifers
- Assign classification as an index



Teo et al. (2017) – in prep

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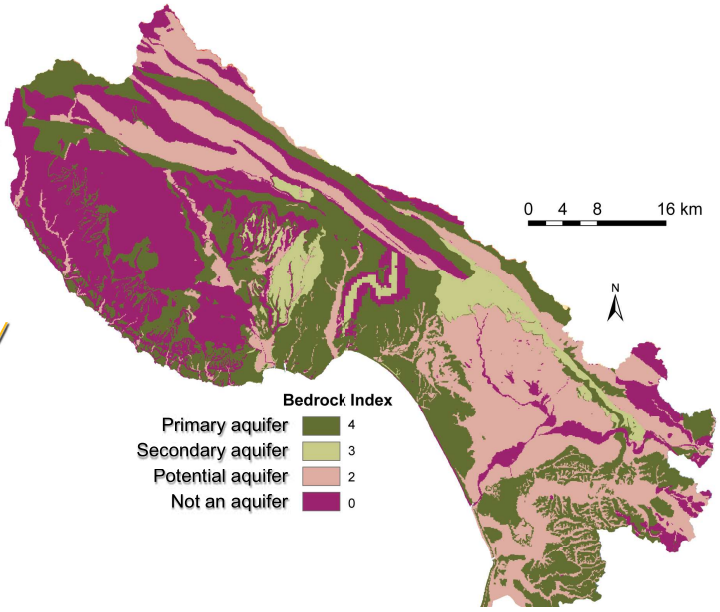
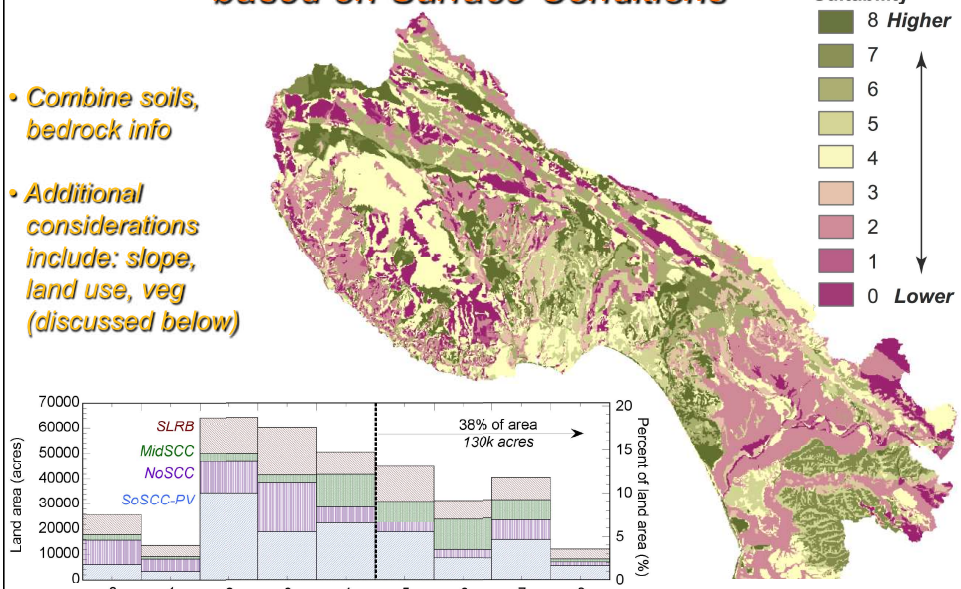


Teo et al. (2017) – in prep

Suitability for Managed Aquifer Recharge based on Surface Conditions

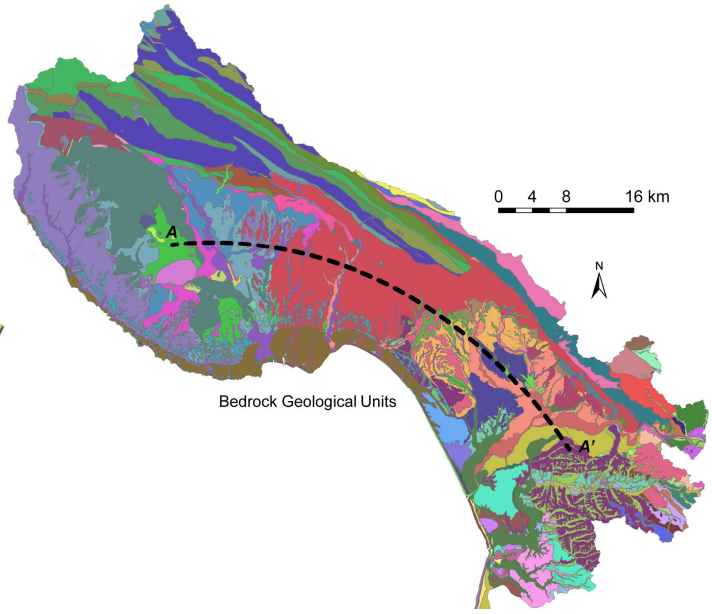
- Combine soils, bedrock info
- Additional considerations include: slope, land use, veg (discussed below)



Teo et al. (2017) – in prep

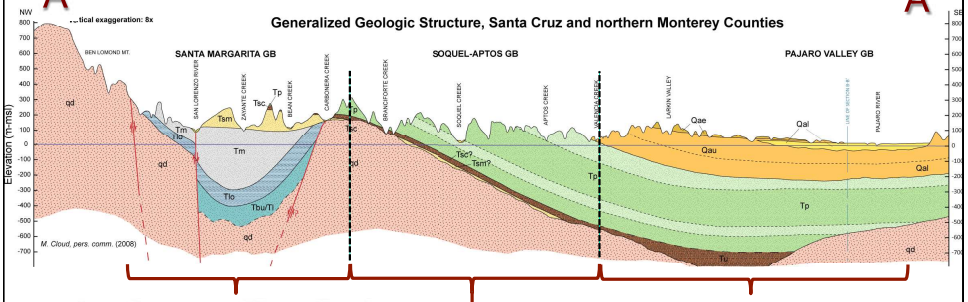
Subsurface Unit Geometry and Properties

- Combine regional data from multiple reports/maps
- Evaluate unit by unit to determine which bedrock units are/might be/ are not aquifers
- Assign classification as an index



Teo et al. (2017) – in prep

One county, three (+?) groundwater basins, all in overdraft…



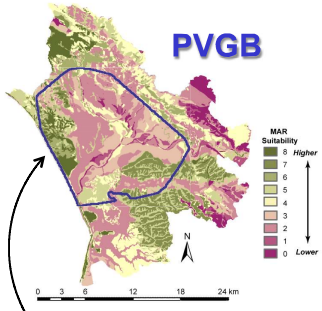
San Lorenzo River Basin
- Mountainous, rural/urban
- GW levels down by 100 m
- Inland, no SW intrusion

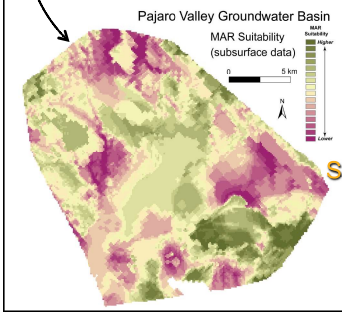
Pajaro Valley GW Basin
- Agricultural, urban, rural
- Considerable SW intrusion
- Special Act District

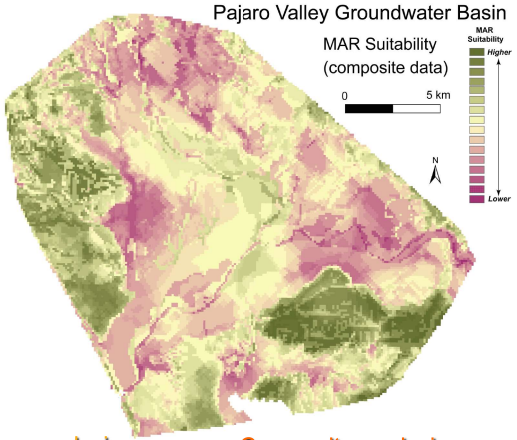
Soquel/Aptos GW Basin
- Mountainous, rural/urban
- First hints of SW intrusion
- Models say: critical overdraft (so does DWR!)

M. Cloud, pers. comm.

Suitability for Managed Aquifer Recharge based on Surface+Subsurface Conditions







Subsurface analysis:
- Transmissivity (*K* x *b*)
- Vadose zone thickness
- Available storage
- Change in storage

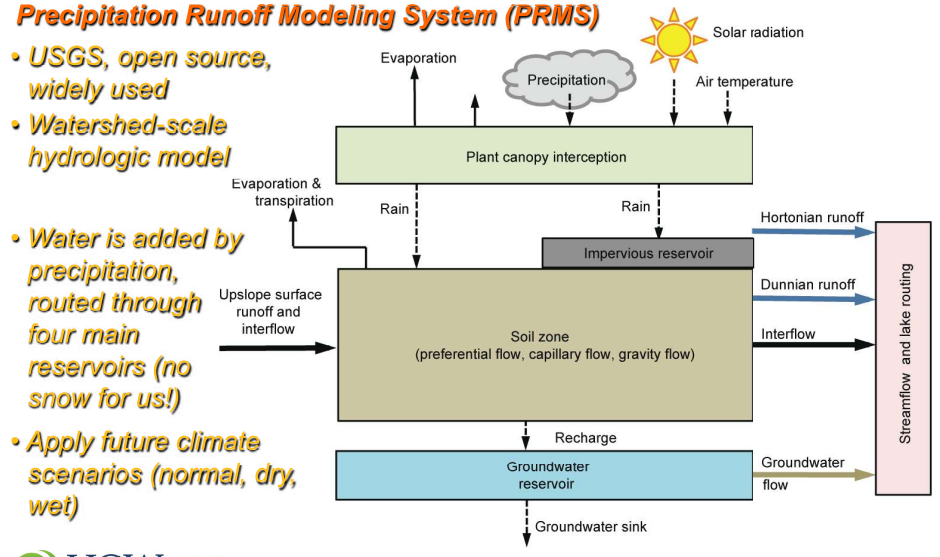
Composite analysis:
covers a fraction of the subregion – where there are subsurface datasets

Teo et al. (2017) – in prep

Where to Collect Stormwater Runoff?

Precipitation Runoff Modeling System (PRMS)

- USGS, open source, widely used
- Watershed-scale hydrologic model
- Water is added by precipitation, routed through four main reservoirs (no snow for us!)
- Apply future climate scenarios (normal, dry, wet)



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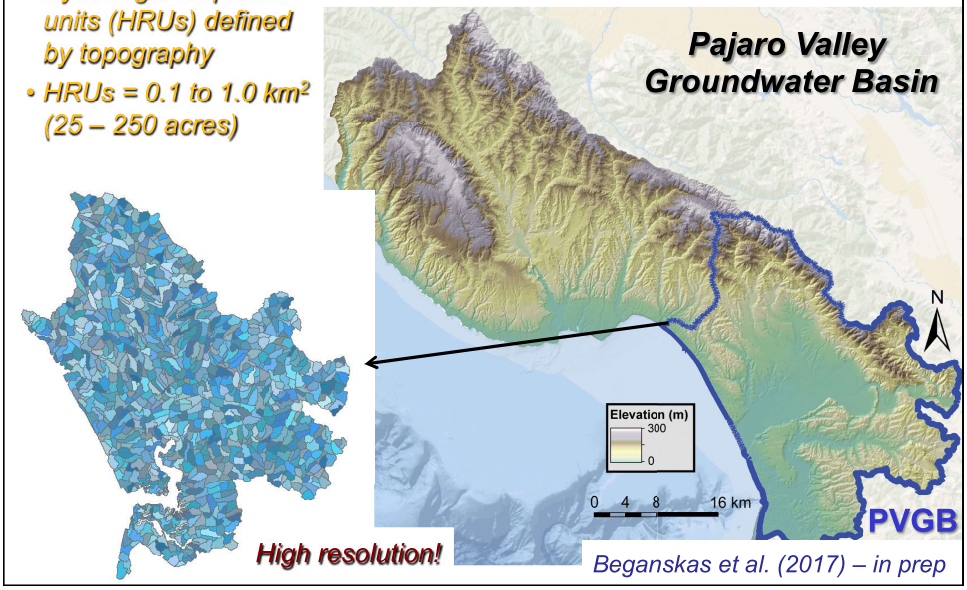
modified from *Markstrom et al. (2015)*

Where to Collect Stormwater Runoff?

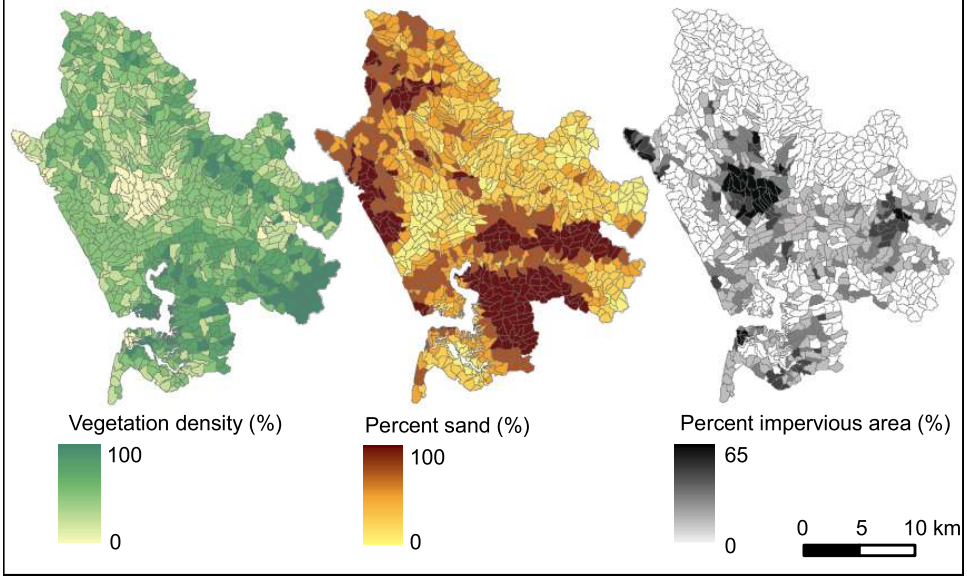
- Hydrologic response units (HRUs) defined by topography
- HRUs = 0.1 to 1.0 km^2 (25 – 250 acres)



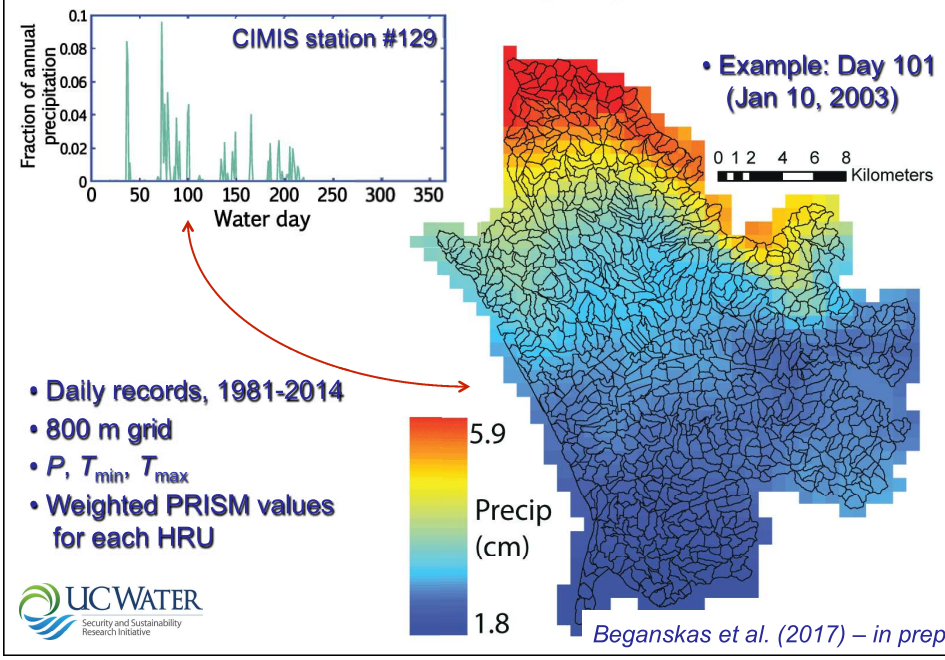
High resolution!

Beganskas et al. (2017) – in prep

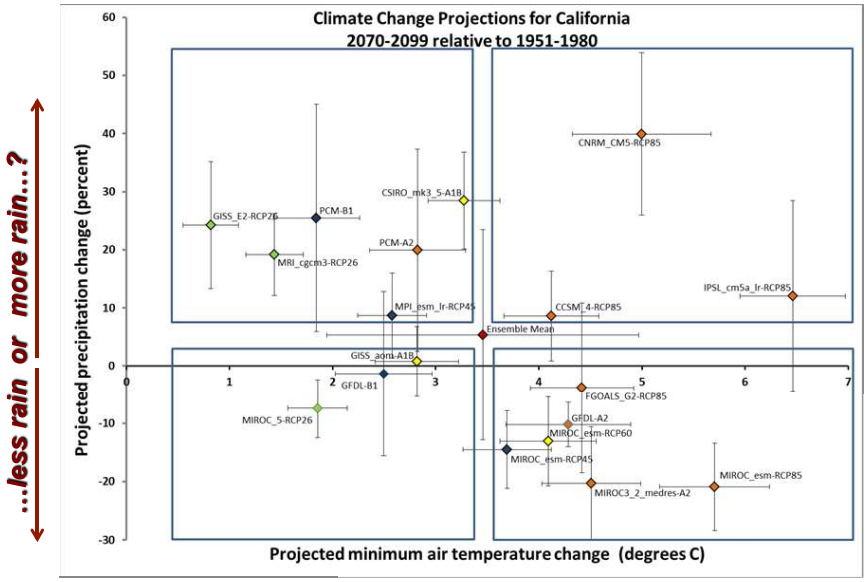
Example model parameters for PRMS



Historical climate data at high spatial resolution



Why not Use Climate Model Output?



18 models, 18 predictions

from Flint and Flint (2014)

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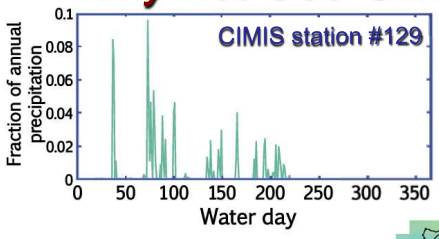

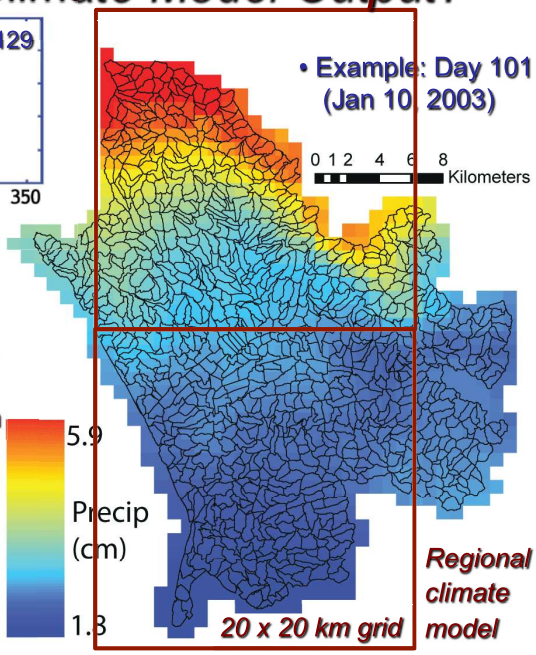

Regional climate models can't replicate ***spatial*** distribution…

Regional climate models can't replicate ***temporal*** distribution (#, length, gap, intensity)…

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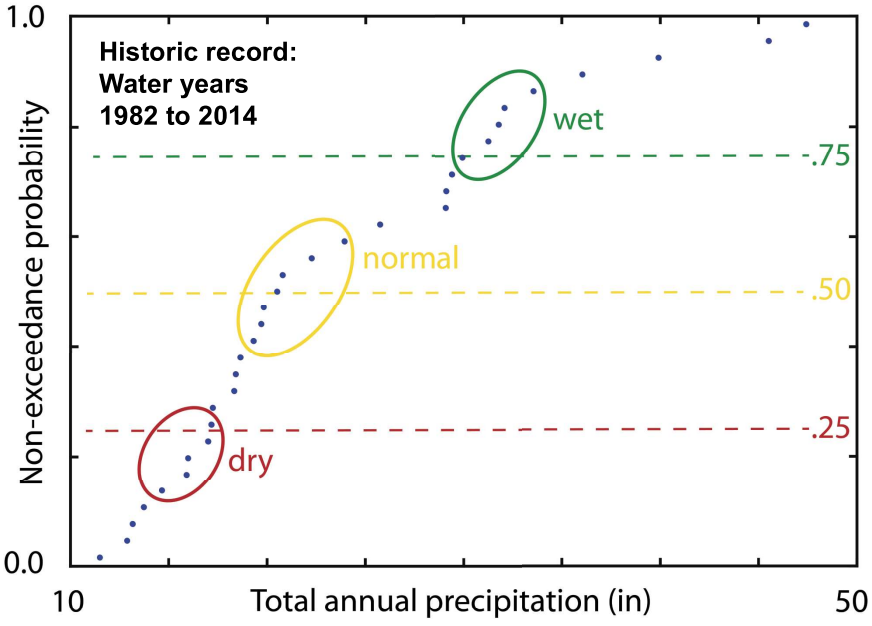
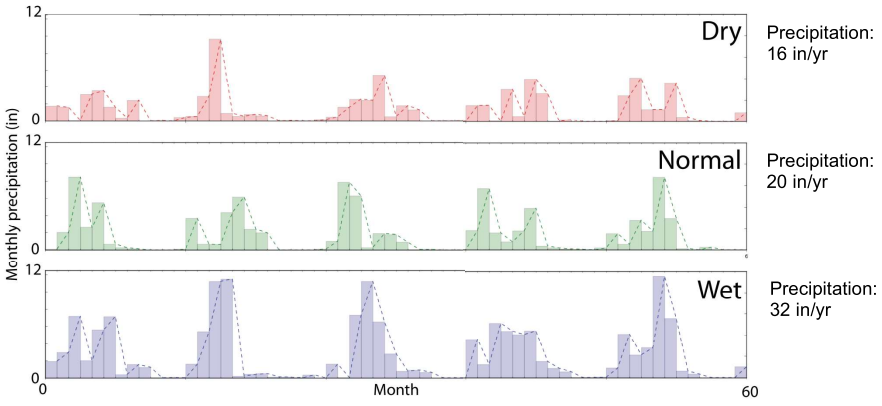
Model Climate Scenarios



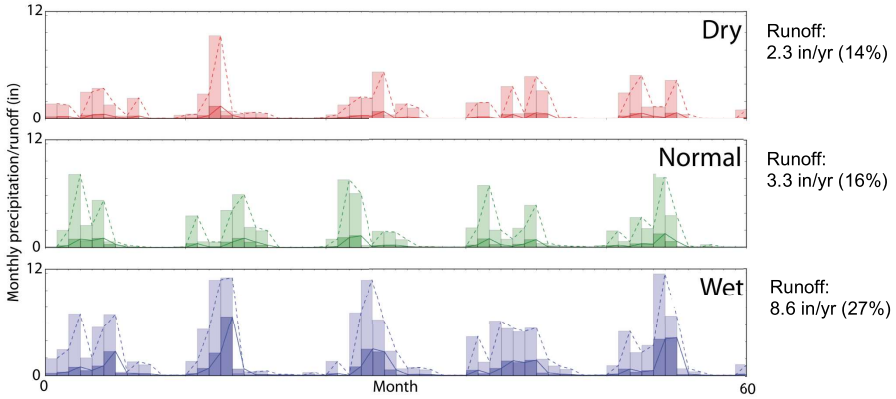
Model Results
Basin-wide precipitation



All climate scenarios have months with significant rainfall

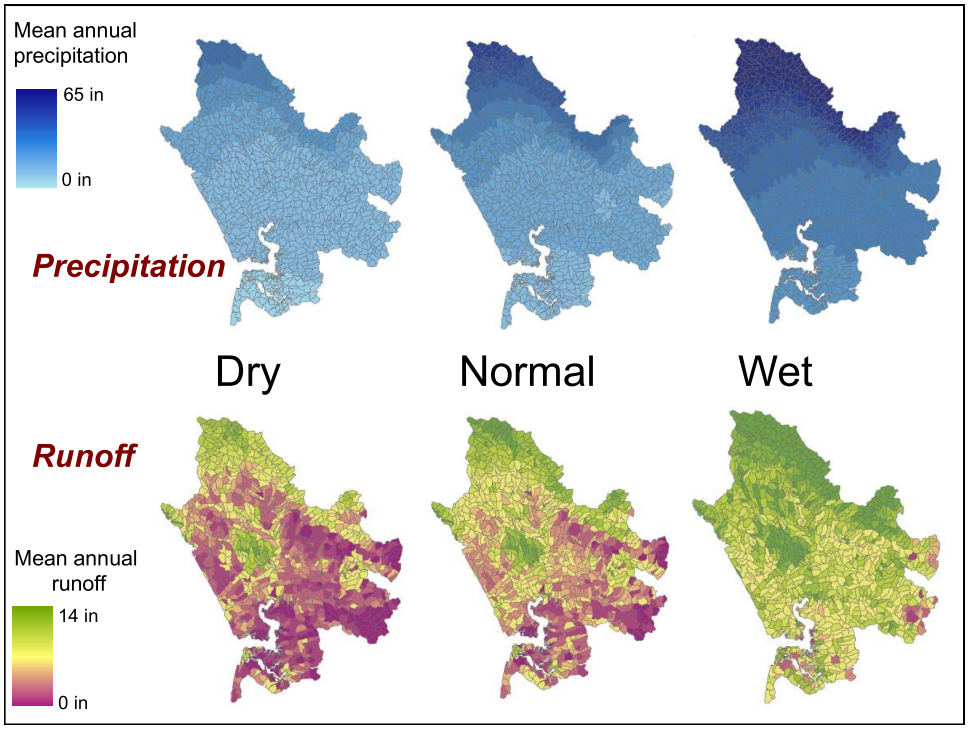
Beganskas et al. (2017) – in prep

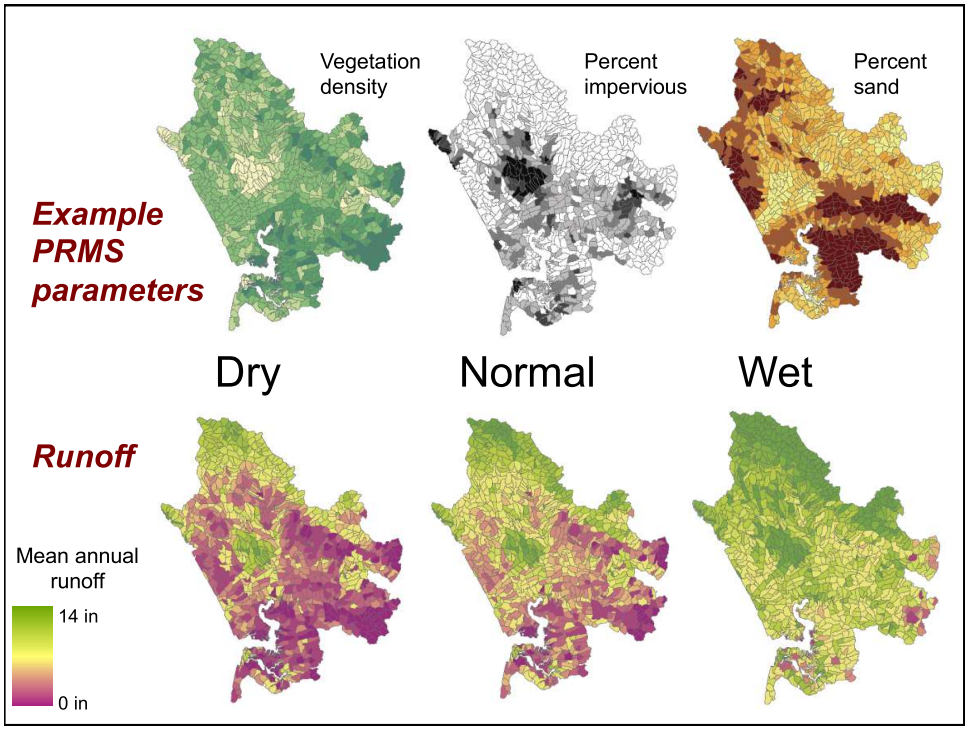
Model Results
Basin-wide precipitation and runoff



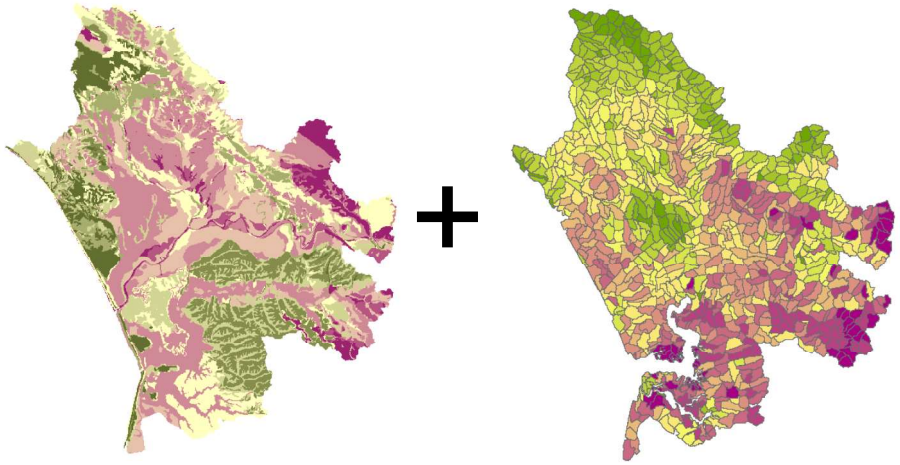
1 inch of runoff = 11,300 acre-feet
There is ample runoff available for collection

Beganskas et al. (2017) – in prep





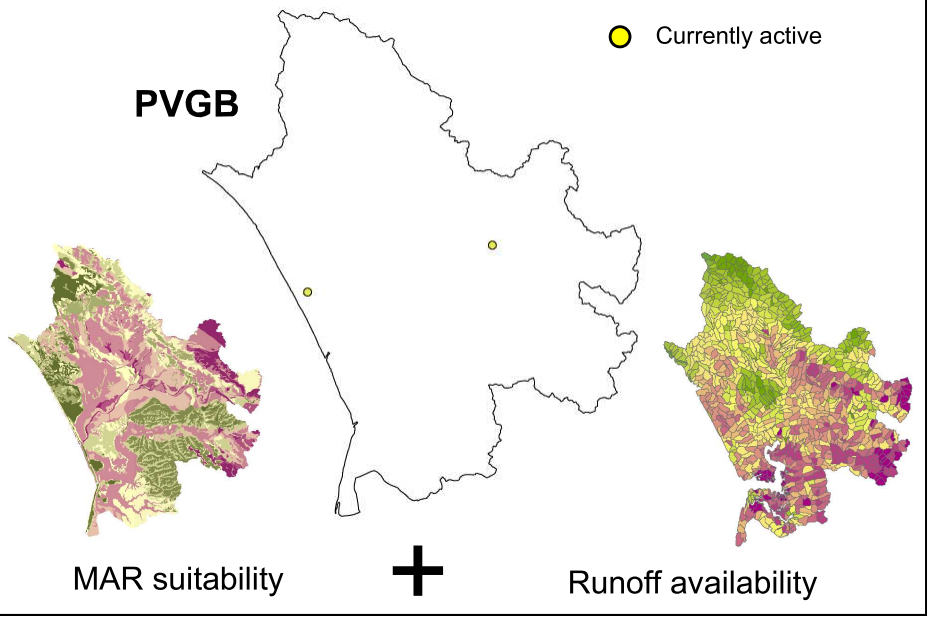
Next steps: combine mapping & modeling



MAR suitability + Runoff availability

- **Assess existing and planned sites**
- **Help to identify and assess new sites**

Screening DSC-MAR project locations



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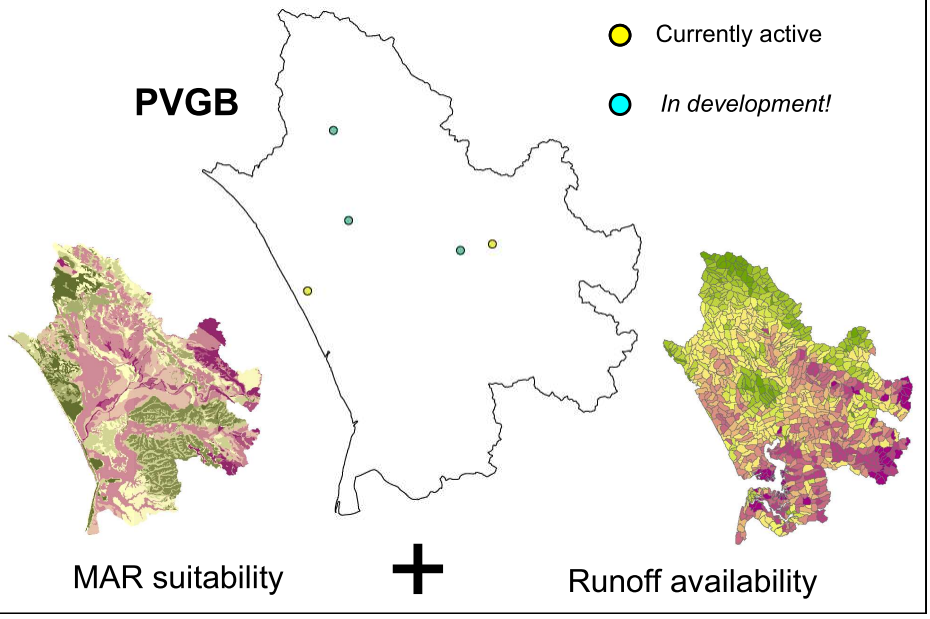
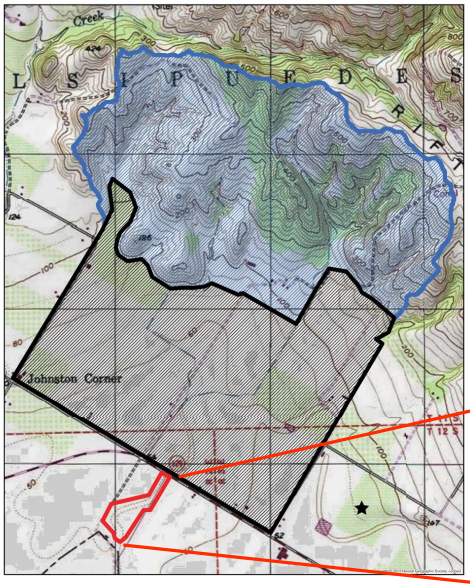


Planned Project Site

- *Working ranch and rangeland*
- *>1300 acres draining into 15 acres*
- *interest in improvement to water supply and water quality*



Locations and areas (approximate)

Developed (620 acres)

Undeveloped/less developed (700 acres)

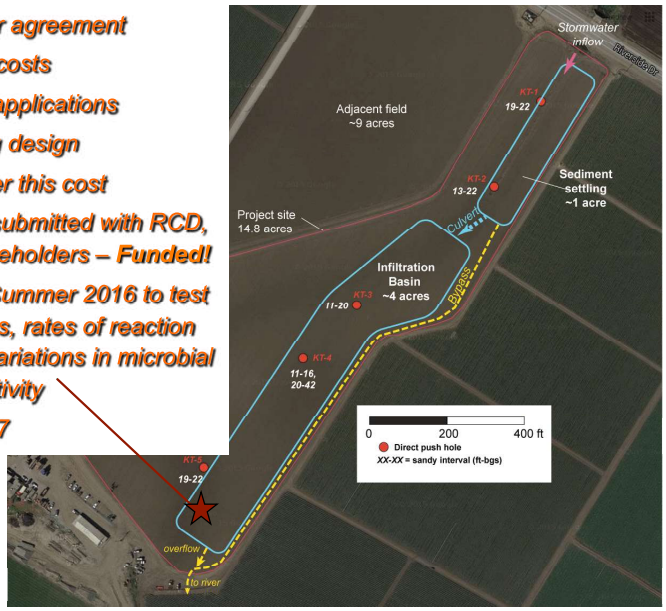
Potential infiltration area

Nearby infiltration project

State of California
Coastal Conservancy

Conceptual project design

- √ *Secured land-owner agreement*
- √ *Survey to estimate costs*
  - *needed for grant applications*
- √ *System engineering design*
  - *landowner to cover this cost*
- √ *Grant applications submitted with RCD, PVWMA, local stakeholders – Funded!*
- √ *Field experiments Summer 2016 to test infiltration properties, rates of reaction during infiltration, variations in microbial populations and activity*
- √ *Construction in 2017*

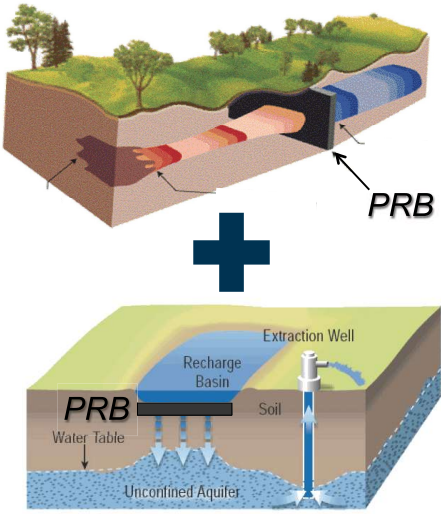


Demonstrated improvements to water quality…

How to Improve Water Quality during DSC-MAR?

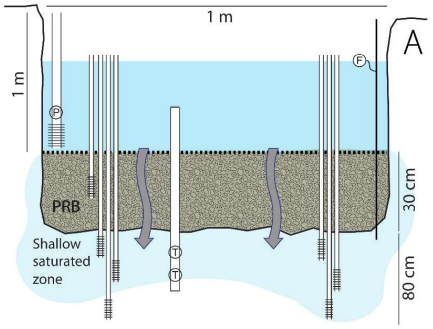
Field and laboratory studies:

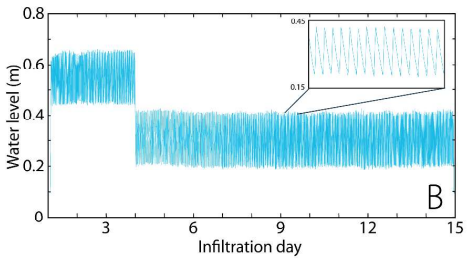
- *What are relations between infiltration rate, microbial activity, and nitrogen cycling?*
- *How can the use of a permeable reactive barrier (PRB) impact these relations?*
- *How can development and use of a low-cost PRB improve water quality during MAR?*

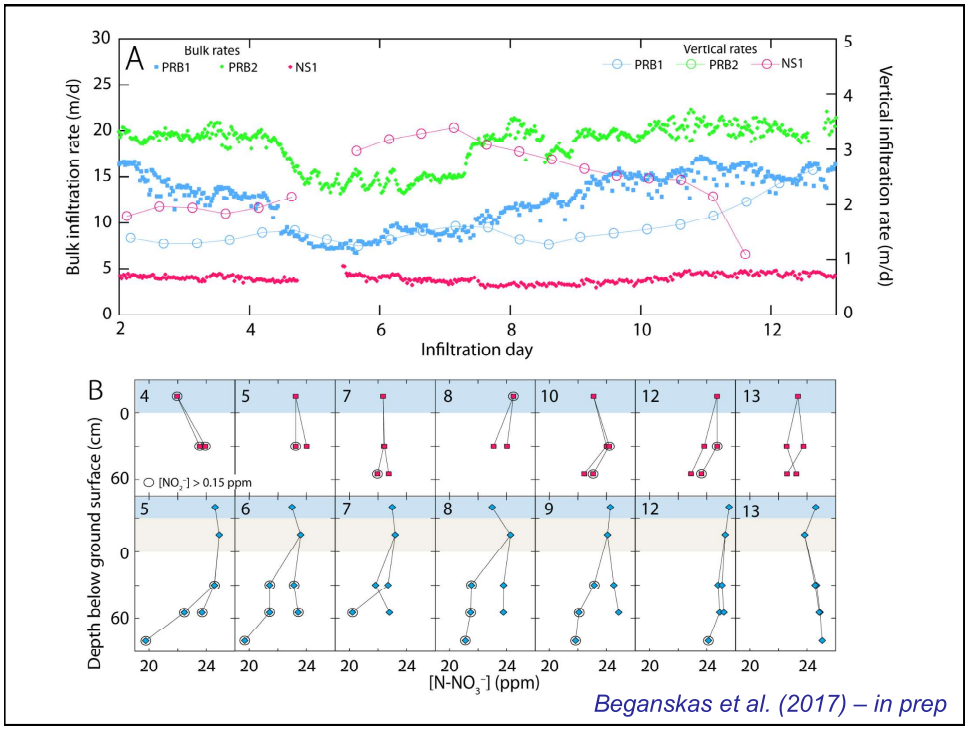


GORDON AND BETTY MOORE FOUNDATION

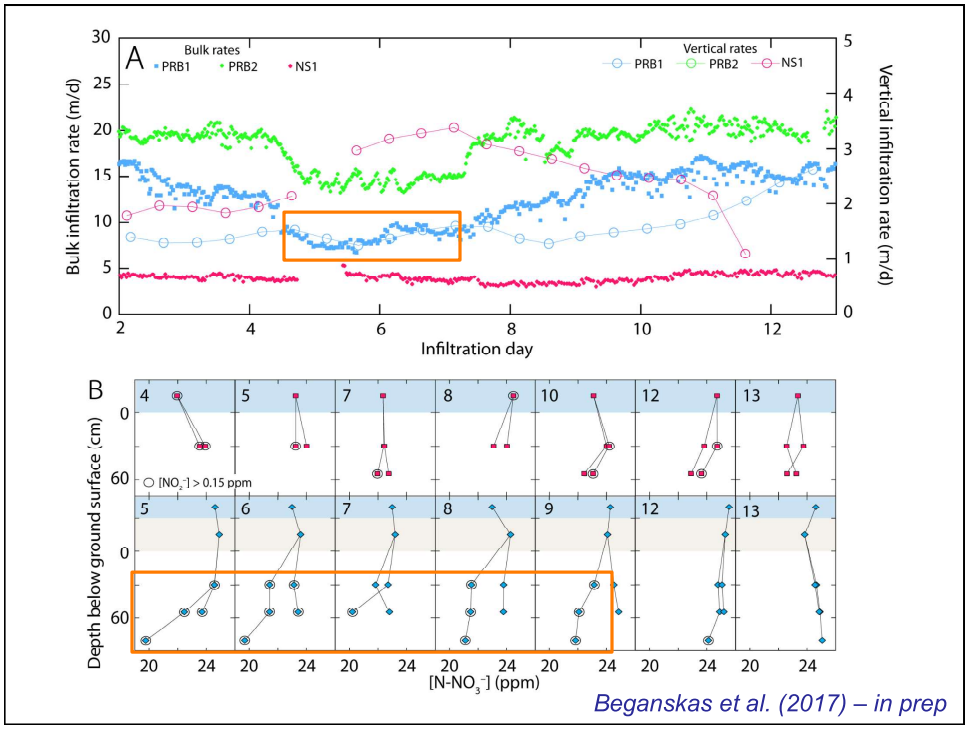
Experimental configuration



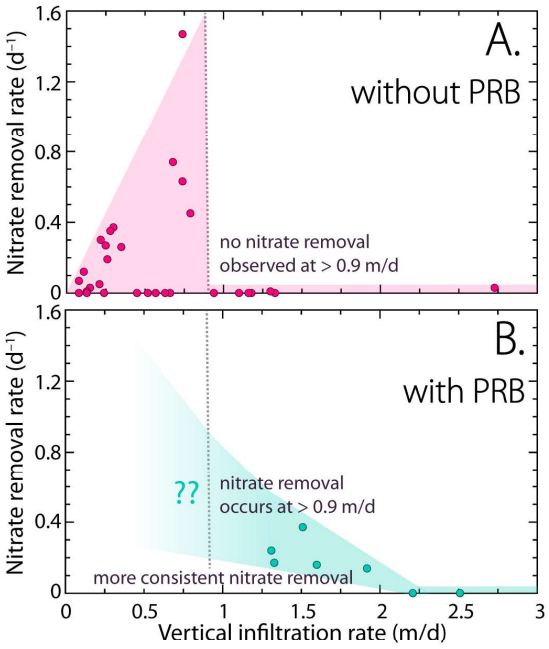




Beganskas et al. (2017) – in prep



Beganskas et al. (2017) – in prep

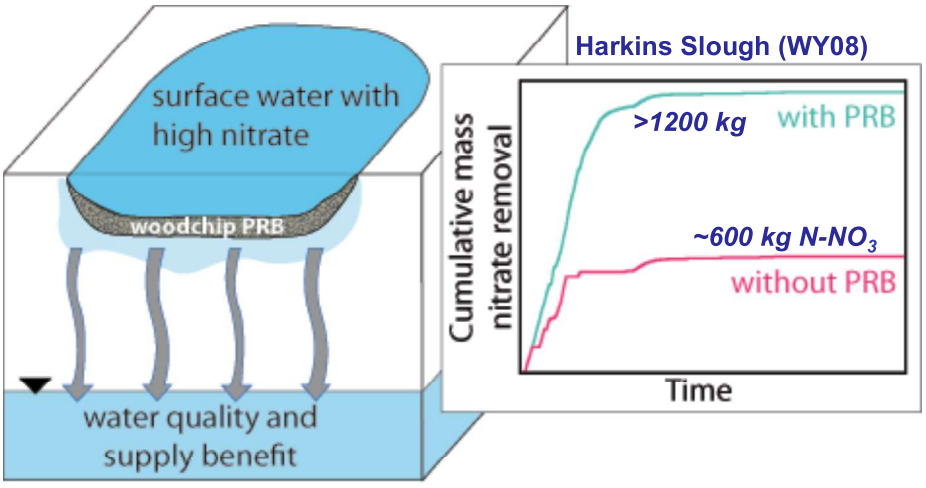


A woodchip PRB can **expand the range of infiltration rates** during which nitrate removal occurs!

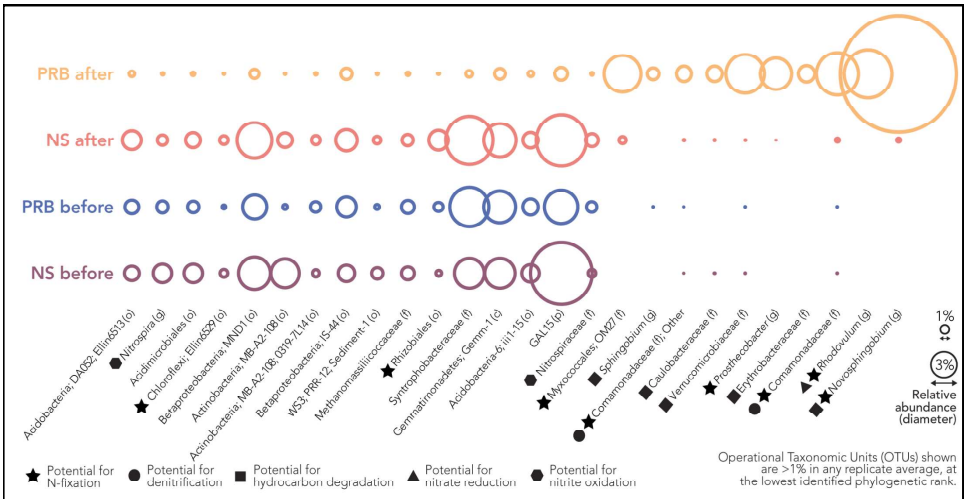
The PRB may also stimulate **more consistent nitrate removal** than native soil

data from Schmidt et al. (2011), Beganskas et al. (2017) – in prep

Applying results at field scale:



data from Schmidt et al. (2011), Beganskas et al. (2017) – in prep



- Infiltration through the PRB was associated with statistically significant shifts in microbial populations.
- Particular increases in communities that fix N, degrade organic compounds, reduce N, and denitrify.
- RNA work in progress…

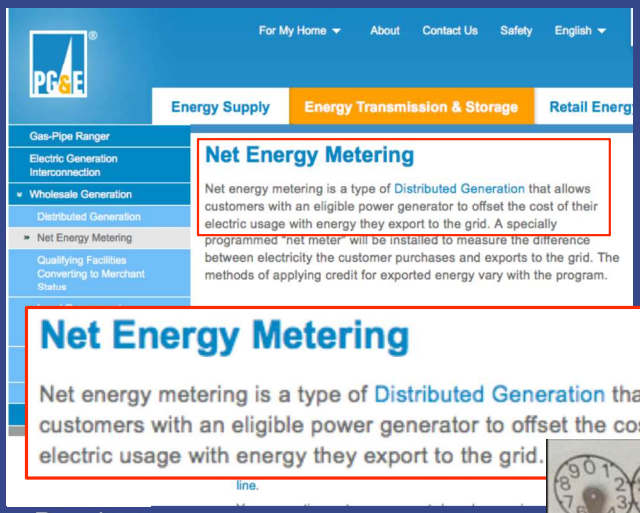
Beganskas et al. (2017) – in prep

Costs to Growers/Landowners for DSC-MAR

- *Land taken from production/reduced access*
- *Maintenance of infiltration structures (basins, dry wells)*

How can participation be incentivized?

There is a Workable Example: Net Energy Metering



- *generate energy locally*
- *account for net usage*
- *excess power goes on the grid for sale (and eventual use)*

- *Requires*
  - *reliable measurement and accounting*
  - *formula to calculate benefit/rebate*
  - *stakeholder and Agency trust*

Example: Net Recharge Calculations

Irrigated area: 75 irrigated acres

Applied water: 2.5 ft

Annual precipitation: 1.5 ft (18 inches)

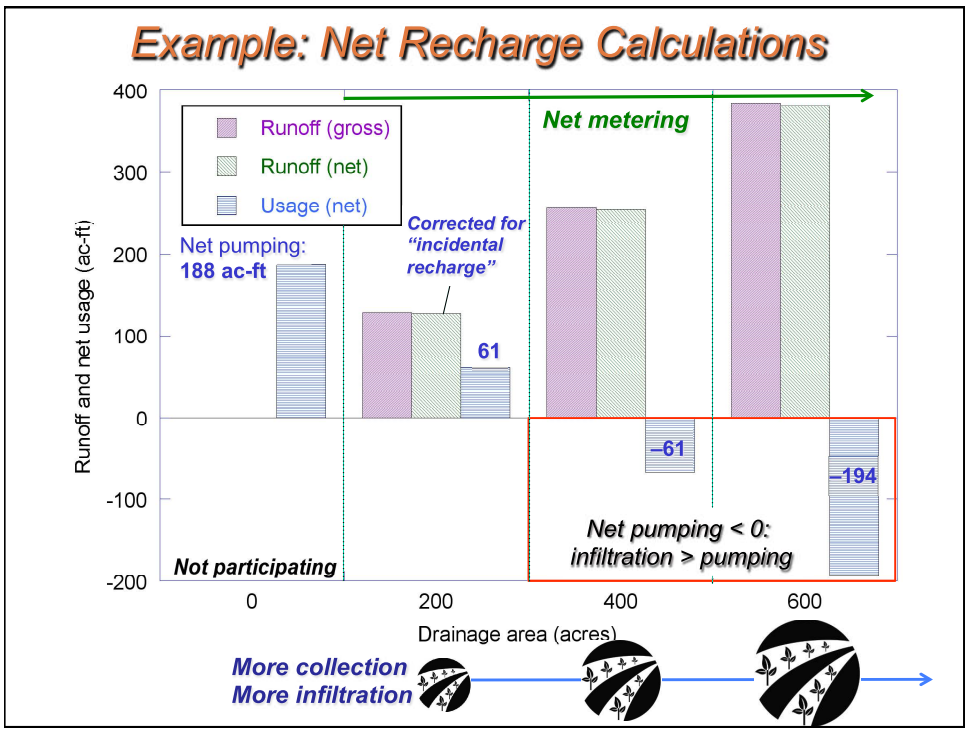
Runoff/precipitation = 0.4 (appropriate for intense events)

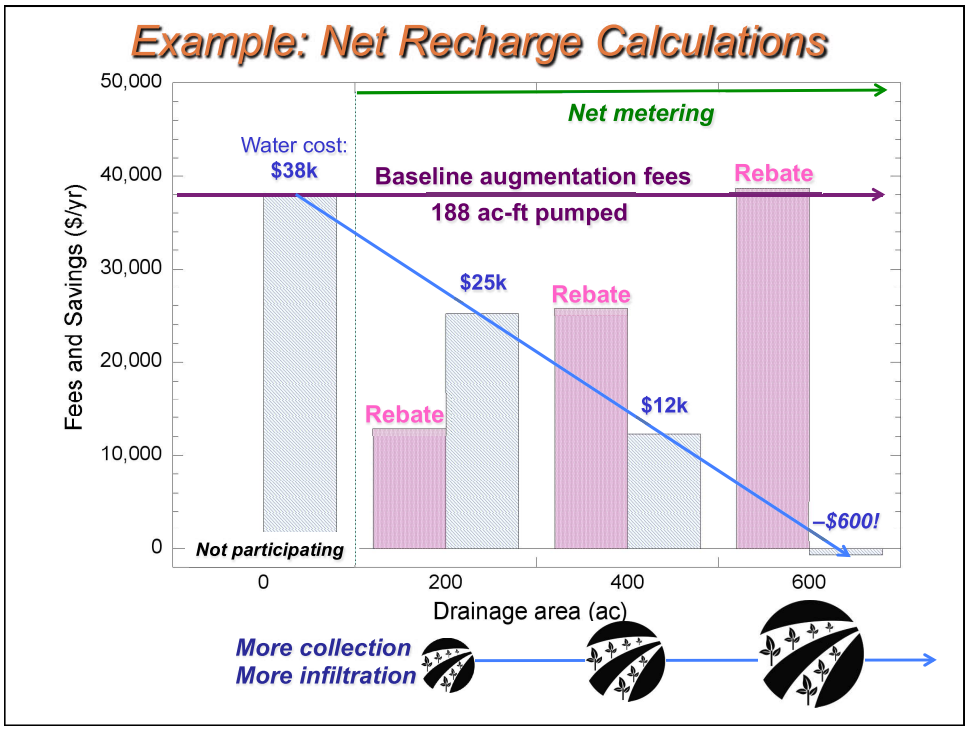
Options:

Drainage:	**200**	**400**	**600 acres**
Infiltration:	**2**	**4**	**6 acres**

Augmentation fee = $203/ac-ft
(***outside*** of Delivered Water Zone)

Recharge Net Metering rebate: 50% of net infiltration


Example: Net Recharge Calculations
Runoff (gross)
Runoff (net)
Usage (net)
Net metering
Net pumping:
188 ac-ft
Corrected for "incidental recharge"
61
–61
–194
Net pumping < 0:
infiltration > pumping
Not participating
Runoff and net usage (ac-ft)
400
300
200
100
0
-100
-200
0
200
400
600
Drainage area (acres)
More collection
More infiltration


Example: Net Recharge Calculations
Net metering
Water cost:
$38k
Baseline augmentation fees
188 ac-ft pumped
Rebate
$25k
Rebate
$12k
Rebate
–$600!
Not participating
Fees and Savings ($/yr)
50,000
40,000
30,000
20,000
10,000
0
0
200
400
600
Drainage area (ac)
More collection
More infiltration

Recharge Net Metering (ReNeM) in the PVGB
(five-year pilot program, 10/2016-9/2021)

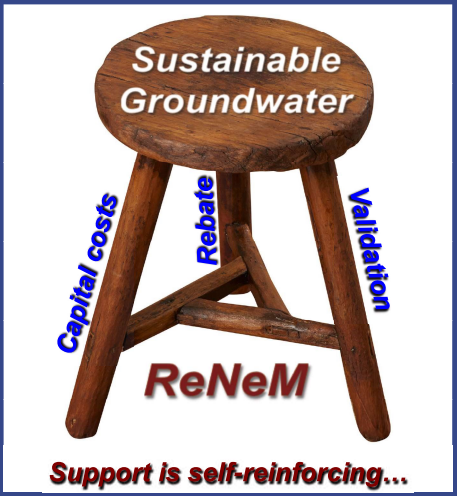
- Goal: 8-10 field projects, each ≥100 ac-ft/yr
- Third-party certifier (TPC) identifies sites, raises capital, develops engineering, plans/builds for measurement
- TPC works with landowners/tenants to validate
- TPC certifies performance, reports to agency
- Agency applies formula to calculate rebate (= credit)

Program status

- One site is operational, three more funded and in development for 2017…
- Multiple requests for site consideration…

Recharge Net Metering (ReNeM)…
…requires three kinds of support

- **Capital costs**
  site ID, design, engineering, installation
- **Validation**
  measurements, sampling, certification
- **Rebates (Incentives)**
  offset for operation and maintenance costs



In the PVGB:

Costs are competitive, program is revenue positive

Recharge Net Metering (ReNeM)…
…is not Groundwater Banking

An aquifer is a bank like a colander is a bucket

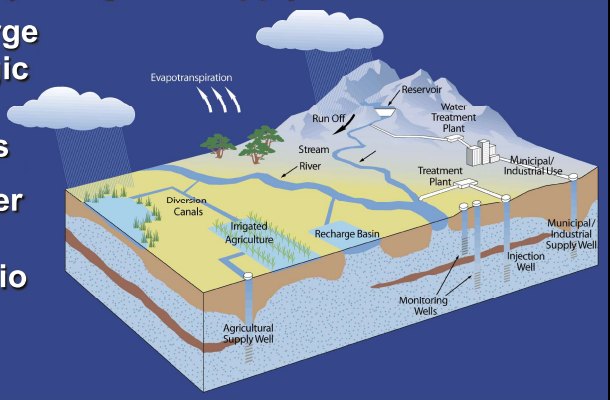
ReNeM:

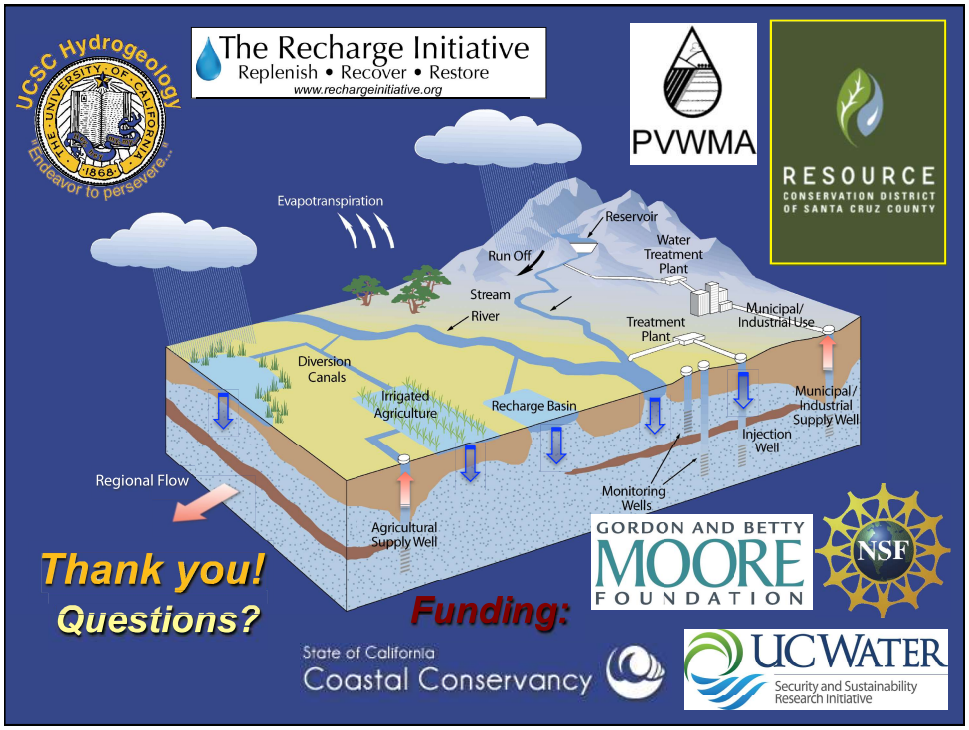
- Incentivizes ***infiltration***, not recharge, not storage
- No water ownership/right is claimed, no recovery is promised
- Rebate is performance based, year by year
- Incentive based on a rebate of fees

Should CA incentivize other GW management activities?

Summary and Ongoing Work

- Stormwater can help to improve groundwater
- *Find the best locations* to enhance recharge
- Design systems to *measure performance*
- Improve water quality along with supply
- Groundwater recharge provides hydrologic system services, justifies incentives
- MAR with stormwater can be part of a successful portfolio for sustaining groundwater




UCSC Hydrogeology
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Replenish • Recover • Restore
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Water
Treatment
Plant
Run Off
Stream
River
Treatment
Plant
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Industrial Use
Diversion
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Irrigated
Agriculture
Recharge Basin
Municipal/
Industrial
Supply Well
Injection
Well
Regional Flow
Monitoring
Wells
Agricultural
Supply Well
Thank you!
Questions?
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